

Nutrient characteristics in rhizosphere of pure and mixed plantations of Manchurian walnut and Dahurian larch

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Abstract: A comparison study was made for the characteristics of pH value, organic matter content, nutrient element N, P and K contents in rhizosphere soils of pure and mixed plantations of Manchurian walnut and Dahurian larch and in bulk soils. The results show that the pH values of rhizosphere soil for all the plantations except the pure walnut stand, which was slightly higher, were lower than those of bulk soils, while the organic matter contents in the rhizosphere soil for all the plantations except the mixed plantation, which was slightly lower, were higher than that in bulk soil. There exists a relative nitrogen accumulation in the rhizosphere and the extent to which the nitrogen accumulates is closely related to tree species and mixed pattern. As far as the total P and K contents are considered, there exists a deficient tendency in rhizosphere in comparison with bulk soil. The element N, P and K are all mobilized in the rhizosphere of the pure or mixed plantation, characterized by the higher contents of the available N, P and K in the rhizosphere. The available N content in the rhizosphere of the larch in mixed plantation was obviously higher than that of its pure plantation, whereas the available P and K contents in the rhizosphere of walnut in the mixed plantation, on the other hand, were significantly higher than those of its pure plantation.

Key word: Rhizosphere soil; Bulk soil; Nutrient mobilization; Pure and mixed plantations

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Introduction

Nutrient status in rhizosphere can directly influence the translocation of nutrients from bulk soil to root, thereby the absorption by roots. Therefore, nutrient status in rhizosphere soil is closely correlated to growth of plants (Liu 1980; Zhang *et al.* 1992; Gardner *et al.* 1982). Plant roots can directly activate and utilize the sparingly soluble nutrients near the roots, which exist in solid state (Gahoonia *et al.* 1992; Clegg *et al.* 1997). There exists an obvious difference in ability to activate the insoluble nutrient among different kinds of plants, even among the different genotypes (Zhang 1992; Gahoonia *et al.* 1992). The changes in the rhizosphere have a significant effect on growth of mixed plantation after two tree

species are mixed. The aim of this paper is to reveal the differences of some physicochemical properties between in rhizosphere and in bulk soil, thereby attempting to discern the nutrient mechanism in which the mixed plantation is superior to the pure plantations.

Material and method

The research site is located in the Maoershan Forestry Experimental Station, between latitude 45°16' N and longitude 127°34' E, affiliated to the Northeast Forestry University. The average annual temperature is 2.8°C. The average annual rainfall and evaporation capacities are 723 mm and 1 293 mm respectively. The zonal soil is typical dark brown forest soil and the forest type belongs to the secondary forest. In 1987, the different types of plantations were formed after clear cutting in strips, including pure walnut plantation, pure larch plantation and their mixed plantation. The distance between plants or rows were all 1.5 m and the two tree species are mixed in strips (3 rows of walnut × 5 rows of larch). The plantations were all 11 years old, without inter-

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mediate cutting, at investigation time. 11 sampling plots were made in each kind of plantation and the non-rhizosphere soil samples were collected at a depth of 0–20 cm. Simultaneously, 15 trees were selected in each plantation type and the rhizosphere soil samples were collected at the same depth as the non-rhizosphere soil by peeling the intact soil adhered to roots. The nutrient contents of soil were all determined by the standard methods issued by the State Standard Bureau.

Results and discussion

pH characteristics in rhizosphere soil

There exists an obvious difference about the pH value between rhizosphere soil and bulk soil, as shown in Table 1. In a whole, the pH values of rhizosphere soil for all the plantations except the pure walnut stand, which was slightly higher, were lower than those of bulk soils. The pH value of rhizosphere of pure larch plantation was 0.45 unit lower than that of bulk soil. The pH values in the rhizosphere soils of the walnut and larch in mixed plantation are 0.09 and 0.23 unit lower than that of bulk soil respectively. The

difference in pH value between rhizosphere soil and bulk soil may be caused by multiple factors, mainly including the differential rate of cation to anion absorbed by roots, gas CO₂ released by roots, organic acid excreted by roots and the microorganisms and so on. The differential rate of cation to anion absorbed by roots is usually considered as one of the major causes of rhizosphere acidification. Generally, plants require much more element nitrogen than any other mineral nutrient. Therefore, the type and number of the nitrogen absorbed by roots usually influence the direction and extent of pH change. When nitrogen is absorbed as NH₄⁺, cation uptake exceeds anion uptake and H⁺ ions are released to balance the charge. Conversely, when nitrogen is absorbed as NO₃⁻, anion uptake is enhanced and OH⁻ or HCO₃⁻ ions are released to balance the excess anion absorption. From the direction of rhizosphere pH change of walnut and larch, we may speculate that more nitrogen is absorbed as NH₄⁺ by larch and more nitrogen is absorbed as NO₃⁻ by walnut. However, this conclusion still needs to be testified by some more experiments.

Table 1. Physiochemical properties of rhizosphere and bulk soils in pure and mixed plantations of walnut and larch

Plantation type	Soil site	pH value	Organic matter /%	Total N /%	Available N /mg·kg ⁻¹	Total P /%	Available P /mg·kg ⁻¹	Total K /%	Available K /mg·kg ⁻¹
Pure walnut	Rhizosphere	6.61	12.64	0.693	88.62	0.148	12.30	1.240	234.6
	Bulk soil	6.53	12.35	0.562	69.34	0.169	10.62	1.561	182.3
Pure larch	Rhizosphere	5.62	11.06	0.573	50.62	0.135	28.66	1.125	288.9
	Bulk soil	6.07	10.17	0.488	41.30	0.142	13.97	1.351	226.5
Mixed plantations	Rhizosphere (W)	6.21	11.73	0.687	87.71	0.150	19.41	1.266	271.2
	Rhizosphere (L)	6.07	11.28	0.594	85.70	0.147	25.11	1.309	280.7
	Bulk soil	6.30	11.39	0.545	67.19	0.153	12.75	1.423	199.4

W: walnut; L: larch.

Organic matter content characteristics in the rhizosphere

The organic matter contents in the rhizosphere and bulk soils are given in Table 1. The organic matter contents in the rhizosphere soil for all the plantations except the mixed plantation, which was slightly lower, were higher than that in bulk soil. The organic matter contents in the rhizosphere soils of the pure walnut and larch plantations were 20.50% and 16.35% higher than in their bulk soils respectively. In mixed plantation, organic matter content in rhizosphere soil of walnut is 18.60% higher than in its bulk soil. The results above showed that rhizosphere was a micro-zone where the organic matter has accumulations relatively. Comparing to bulk soil, the rhizosphere has higher organic matter content by reason of the excretion of the organic matter by root and the removal of root hairs. Besides, much larger quantities of the microbes in rhizosphere may be

also one of the reasons for higher organic matter content in rhizosphere.

Nitrogen content characteristics in the rhizosphere

For all the plantations, the total N contents of rhizosphere soil were obviously higher than that of bulk soil (Table 1). The total N contents of rhizosphere soil under pure walnut and pure larch plantations were 23.3% and 17.42% higher than that of bulk soils respectively. For the walnut and larch in mixed plantation, total N content of rhizosphere soil of was 26.10% and 9.00% higher than those of bulk soils. The results above show that there exists a relative nitrogen accumulation in the rhizosphere and the extent to which the nitrogen accumulates is closely related to the tree species and mixed pattern. The factor affecting nitrogen accumulation in rhizosphere soil is mainly the exudates from root and microor-

ganisms, which is hundreds of times more than in the bulk soil.

The available N content in rhizosphere was also apparently higher than in bulk soil under every plantation type, which predicts that the translocation rate of the inorganic nitrogen is faster than its absorption rate of root. In pure plantations, the available N contents in rhizosphere of pure walnut and larch plantations were 27.80% and 22.64% higher than in their bulk soils respectively. As to walnut and larch in mixed plantation, the available N contents in rhizosphere were 30.54% and 27.55% higher than in the bulk soil respectively. Another phenomenon deserving noticing is that the available N content in the rhizosphere of larch in mixed plantation is obviously higher than that of its pure plantation. The increase of available N in rhizosphere of larch favors its rapid growth in mixed plantation.

Phosphorus content characteristics of rhizosphere

As far as total P content is considered, there exists a tendency of deficiency in rhizosphere in comparison with bulk soil. However, the deficiency rate of total P in rhizosphere of walnut in mixed plantation decreases apparently, in comparison with that in its pure plantation. It can be said that the phosphorus status of rhizosphere of walnut is enhanced after the two tree species are mixed. As to the deficiency rate of phosphorus in rhizosphere, the pure larch plantation does not, on the other hand, considerably differ from that of larch in the mixed plantation. Conversely, the available P contents in rhizosphere of all plantation types all increase in comparison with the bulk soils, especially in case of pure larch plantation. The available P content in rhizosphere of pure larch plantation is almost two times more than in its bulk soil. Nevertheless, the available P content in the rhizosphere of the pure walnut plantation is only 1.2 times bigger than in its bulk soil. This result shows that the roots of larch can improve mobilization of rock phosphate of rhizosphere more efficiently, which results in an increase of available P. This mechanism, by which the rock phosphate is mobilized, may be correlated to rhizosphere acidification. Another remarkable aspect deserving emphasizing is that the available P content in rhizosphere soil of walnut in mixed plantation increase considerably in comparison with its pure plantation after mixed with larch. It can be said from the results above that the available P status in the rhizosphere of walnut is improved considerably after the mixed plantation is formed. It is necessary to interpret the mechanism by which the rock phosphate in the rhizosphere of walnut is mobi-

lized more efficiently after mixed with larch.

Potassium content characteristics of rhizosphere

The characteristics of total K contents in rhizosphere of all the plantation types are similar to those of total P contents. There exist different deficiency of total K in rhizosphere in comparison with the bulk soil. The deficiency rates of total K in rhizosphere are 20.6% and 16.7% respectively in the pure walnut and larch plantations, while that of walnut and larch in mixed plantation decrease remarkably, with a deficiency rate of 11.0% and 8.0% respectively.

The available K content in rhizosphere of every plantation type was higher than in its bulk soil. For pure walnut and larch plantations, it was 28.7% and 27.5% higher than in the bulk soil respectively, while for the walnut and larch in mixed plantation it was 36.0% and 40.7% higher than in the bulk soil respectively. It can be concluded that the element potassium is also activated in the rhizosphere and the extent to which the potassium is activated is relevant to the tree species and the mixed pattern. The available K content in the rhizosphere soil of the walnut in the mixed plantation is obviously higher than in its pure plantation, which is helpful to the growth improvement of walnut in the mixed plantation.

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